

## RF-Enablement of Products and Receptacles Therefor

## DESCRIPTION

Cross-reference to related application

[Para 1] This application claims priority from US application number 60/589,524, filed July 20, 2004, which application is incorporated herein by reference for all purposes.

#### Background

[Para 2] This invention relates to identification and tracking of products, receptacles (including containers, boxes, and pallets), and other objects as they are transported and stored in moving through the supply chain from manufacturer to end-user. More particularly, the invention relates to the use of RFID tags and antennas therefor in receptacles, products, methods, and systems to achieve full visibility of products throughout the levels of their supply chain.

[Para 3] High-value products such as medical devices must often be tracked traced and details recorded as it moves through a supply chain. In many cases the medical device itself is temperature sensitive, and time sensitive, and may have a specific expiry date. Many of these medical devices may be worth thousands to even tens of thousands of dollars. Therefore, security tracking and optimized inventory may be not only critical to the business but also could provide audit trial information that may be required by governmental authorities, such as the FDA (the United States Food and Drug Administration).

[Para 4] Many have proposed or discussed the use of radio frequency tags or what is now known as RF ID to track these high-value assets through a supply chain (e.g. US5774S76, US5S04S10). In most cases these RF tags are placed either inside the box

containing-the asset, or placed outside the box using an adhesive tape or other attachment means. These tags are read by a mobile reader or in some cases by a fixed reader to identify the product. Moreover, smart radio tags can use features such as a Liquid Crystal Display (LCD) to indicate status of the asset; temperature sensors to provide data logs and alarms if certain temperature parameters are not met; light emitting diodes or LEDs as indicators to make picking and putting the asset optimal; and buttons and that may be used to detect whether the tag is attached too a package or enabling human input to the tag. These tags may typically be the size of the credit card or slightly larger. However several serious problems arise when tracking high-value assets that require full pedigree audits and reliable proof that the medical device (e.g. stent) or other product has not been tampered with, as well as to provide many other options.

#### Summary of the invention

[Para 5] Broadly and generally, the present invention provides integration of either entire RFID tags or only antennas thereof into objects, such as products (e.g. medical stents, CD's (compact discs), prescription medicine bottles) and receptacles (e.g. containers, packages, boxes, ULD's (unit load devices, as used in air freight), warehouse shelving, and the like) used to hold products.

[Para 6] Accordingly, the present invention provides an object operable for communicating wireless radio frequency (RF) signals, the aforesaid object comprising an antenna integrated (for example, an embedded ferrite loop) therewith.

[Para 7] Preferably, the aforesaid integrated antenna may be embedded into the aforesaid object (e.g. a CD/compact disk; a ULD (Unit Load Device), meat tray or other receptacle).

[Para 8] Moreover, the aforesaid integrated antenna should preferably have a dimension thereof that is substantially as large as a dimension of said object. The use of large antennas is particularly advantageous for low RF signal frequencies not exceeding 15 megahertz, and preferably not exceeding 1 megahertz. Moreover, the aforesaid integrated antenna may preferably comprise a loop integrated into the aforesaid object in each of two substantially orthogonal dimensions thereof.

[Para 9] According to a preferred embodiment, the aforesaid object comprises a product (e.g. stent) and an RFID tag attached thereto (e.g. integrated therewith), the aforesaid RFID tag comprising a transmitter and a tag antenna (preferably much smaller than the integrated antenna) operable to transmit wireless RF signals to the aforesaid integrated antenna.

[Para 10] Preferably, the aforesaid RFID tag is passive and further comprises a receiver, a microprocessor, a data storage device operable to store a selected code (e.g. an ID code to identify said object or said product), the aforesaid tag antenna being operable to receive incoming wireless RF signals from the integrated antenna and to communicate them to the receiver, the receiver being operable to communicate them to the microprocessor, the microprocessor being operable to read the aforesaid selected code (e.g. the aforesaid ID code) from the aforesaid data storage device in response to a selected set of said incoming wireless RF signals and to transmit such selected code wirelessly from the tag antenna to the integrated antenna, the integrated antenna being operable thereupon to transmit the aforesaid ID code wirelessly to a field antenna, which can communicate with the directly or by satellite to a central station or the internet.

[Para 11] According to another preferred embodiment, the aforesaid object comprises a receptacle and an RFID tag attached thereto (e.g. integrated therewith), the aforesaid RFID

tag comprising a transmitter and a tag antenna operable to transmit wireless RF signals to the aforesaid integrated antenna.

[Para 12] According to another preferred embodiment, the aforesaid RFID tag is active and further comprises a microprocessor, a data storage device operable to store a selected code (e.g. an ID code to identify said object or said product), the aforesaid object comprising a display for displaying the aforesaid selected code upon a signal from the aforesaid microprocessor and an energy storage device (e.g. a lithium ion battery), operable to energize the microprocessor, the display, and the transmitter.

[Para 13] Preferably, the aforesaid receptacle is operable to hold a product, the receptacle comprising a sensor operable to generate a signal characteristic of a condition (e.g. temperature, jog, etc.) experienced by the aforesaid product.

[Para 14] Thus, the aforesaid object may comprise a receptacle (e.g. a tray for holding meat), such receptacle being operable to receive and hold a product (e.g. a steak, a stent), such product having an RFID tag attached thereto and being operable for communicating the wireless radio signals (e.g. of a frequency not exceeding 1 MHZ) between said product and the aforesaid integrated antenna in the aforesaid receptacle.

[Para 15] The invention also provides a receptacle comprising:

- o a body portion operable to hold a product,
- o an RFID tag attached to the aforesaid body portion, the aforesaid RFID tag comprising a receiver, a transmitter, and an antenna, the aforesaid antenna being integrated into a unitary relationship with the aforesaid body portion.

[Para 15] Preferably, the aforesaid RFID tag is operable to receive and transmit wirelessly at a frequency not exceeding 15 megahertz, with even lower frequencies not exceeding 1 megahertz, and even 300 kilohertz) being especially desirable for greater signal strength.

[Para 17] Preferably, the aforesaid antenna comprises a loop antenna designed for superior strength of signal reception by having dimensions thereof scaled to dimensions of said body portion, and has a dimension thereof that is substantially as large as to a maximum dimension of said receptacle. Moreover, the loop antenna preferably comprises a loop integrated into the aforesaid receptacle in each of two substantially orthogonal dimensions thereof.

[Para 18] Preferably, the aforesaid receptacle comprises a container operable to enclose the aforesaid product, such container further comprising a sensor disposed on a surface of the container and operable to generate a sealing signal indicating sealing of such container upon shrink-wrapping thereof.

[Para 19] Moreover, the aforesaid receptacle may comprise a container operable to enclose the aforesaid product, the aforesaid RFID tag further comprising a sensor disposed within such container and operable to generate a signal characteristic of a condition experienced by the product (e.g. temperature, light exposure, weight, humidity, and shock impulse (j<sup>o</sup>9))- Preferably, the aforesaid RFID tag further comprises an indicator element for indicating impending expiry of viability of said product, as by providing a signal selected from visible light and audible sound. Such indicator element may comprise colored LED's, a blinking lamp, or an LCD display.

[Para 20] Preferably, the aforesaid receptacle comprises a stackable container which is adapted for stacking upon other stackable containers to expose a surface of said stackable container for visual inspection, such stackable container further comprising an indicator element disposed on said surface and operable for indicating a condition selected from

- o a) temperature of said product,
- o b) sealing of said receptacle,

- o d) weight of said product,
- o e) humidity within said stackable container,
- o f) jog/shock imposed on said container, and
- o g) impending expiry of viability of said product.

[Para 21] According to a preferred embodiment, the aforesaid receptacle may comprise a pallet, ULD, warehouse shelving unit operable to hold a plurality of containers with integrated antennas or entire RFID tags, each antenna having a dimension thereof that is substantially as large as a maximum dimension of such pallet, ULD, or warehouse shelving unit.

[Para 22] The invention also provides a method of tracking the conditions of products, each such condition being selected from temperature, product enclosure (shrink-wrapping), light level, product weight, humidity, jog, product age/expiry, and product location (GPS coordinates), the aforesaid method comprising the steps of :

- o a) placing each product onto a first receptacle, such first receptacle being provided with a sensor for an aforesaid condition and a passive RFID tag operable to emit first wireless signals that indicate a such condition of said product,
- o b) placing the aforesaid first receptacle into a second receptacle, such second receptacle being provided with a sensor for a such condition and an active RFID tag operable to receive such first signals and to emit second signals, at a wireless frequency not exceeding 15 megahertz, that indicate an aforesaid condition of a first or second receptacle.
- o c) detecting signals selected from the aforesaid first signals and the aforesaid second signals.

o e) providing a visual or audible indication of a said condition.

[Para 24] Moreover, the aforesaid first receptacle may comprise a first antenna integrated therewith. Also, the aforesaid second receptacle may comprising a second antenna integrated therewith.

[Para 25] The invention further provides a method of tracking the conditions of products, each such condition being selected from temperature, product enclosure (shrink-wrapping), light level, product weight, humidity, jog, product age/expiry, and product location (GPS coordinates), the aforesaid method comprising the steps of :

- o a) integrating a passive RFID tag with a product, such passive RFID tag comprising a product antenna integrated into the product, such passive RFID tag being operable to emit wireless RF identification (ID) signals operable to identify the aforesaid product in response to a wireless RF interrogation signal;
- o b) placing the aforesaid product onto a first receptacle, such first receptacle being provided with a sensor for a said condition and an active RFID tag operable to emit the aforesaid RF interrogation signal, to receive the aforesaid ID signals, and to emit first RF signals operable to identify the aforesaid product and to indicate an aforesaid condition at the aforesaid first receptacle,
- o c) placing the aforesaid first receptacle into a second receptacle, the aforesaid second receptacle being provided with a sensor for an aforesaid condition and an active RFID tag operable to receive the aforesaid first signals and to emit second RF signals that indicate an aforesaid condition at one of the aforesaid first and second receptacles,
- o d) detecting auditable signals selected from the aforesaid first RF signals and the aforesaid second RF signals
- o e) transmitting auditable signals (e.g. by cable or by high frequency RF) detected at step

[Para 26] This method may preferably further comprise the step of  
o e) providing a visual (e.g. on an LCD display) or audible (e.g. an alarm bell) indication of  
a the aforesaid condition.

[Para 27] Preferably, the first receptacle comprises a first antenna integrated therewith.

Also,

[Para 28] The aforesaid second receptacle comprising a second antenna integrated  
therewith.

[Para 29] Preferably, the aforesaid first and second RF signals have a frequency not  
exceeding 1 megahertz.

[Para 30] The invention further broadly provides a system of tracking the conditions of  
products, each said condition being selected from temperature, product enclosure (shrink-  
wrapping), light level, product weight, humidity, jog, product age/expiry, and product  
location (GPS coordinates), the aforesaid system comprising:

- o a) a passive RFID tag integrated with an aforesaid product, such passive RFID tag  
comprising a product antenna integrated into said product, such passive RFID tag being  
operable to emit wireless RF identification (ID) signals operable to identify the aforesaid  
product in response to a wireless RF interrogation signal;
- o b) a first receptacle operable to hold the aforesaid product, the aforesaid first receptacle  
being provided with a sensor for a said condition and an active RFID tag operable to emit  
the aforesaid RF interrogation signal, to receive the aforesaid ID signals, and to emit first RF  
signals operable to identify the aforesaid product and to indicate an aforesaid condition at  
the aforesaid first receptacle,
- Q c) a second receptacle operable to hold the aforesaid first receptacle, the aforesaid  
second receptacle being provided with a sensor for an aforesaid condition and an active

RFID tag operable to receive the aforesaid first signals and to emit second RF signals that indicate an aforesaid condition at one of the aforesaid first and second receptacles,

o d) afield antenna operable to detect auditable signals selected from the aforesaid first RF signals and aforesaid second RF signals

o e) a transmitter operable to transmit auditable signals (e.g. by cable or by high frequency RF) detected at step (d) to a central station (e.g. via a satellite) for auditable recording thereat (e.g. on a write-once-only CD ).

[Para 3T] The aforesaid system may further comprise:

o e) an indicator operable to providing a visual (e.g. on an LCD display) or audible (e.g. an alarm bell) indication of an aforesaid condition.

[Para 32] Preferably, the aforesaid first receptacle comprises a first antenna integrated therewith. Also, the aforesaid second receptacle comprises a second antenna integrated therewith.

[Para 33] Preferably, the aforesaid first receptacle comprises a stackable box, the aforesaid second receptacle being selected from a pallet, a ULD Unit Load Device), and a warehouse shelving unit.

#### Description of the drawing

[Para 34] FIG 1 is a schematic view of a novel receptacle (a Smart Package ) with an integrated antenna and RFID tag, in accordance with the present invention.

[Para 35] FIG 2 is a schematic view of a novel receptacle with an integrated antenna and active RFID tag and of a novel product (packaged stent) with an integrated antenna and a passive RFID tag.

[Para 36] FIG 3 is a schematic view of a novel receptacle with sensors therein.

[Para 37] FIG 4 is a schematic view of a novel receptacle in the form of a tote with an integrated antenna and active tag and of a number of smaller receptacles in the form of product containers with active tags integrated therein.

[Para 38] FIG 5 is a schematic view of a novel receptacle in the form of a pallet with an integrated antenna and active tag and of a number of smaller receptacles in the form of product containers with active tags integrated therein.

[Para 39] FIG 6 is a schematic view of a novel receptacle in the form of a tote with an integrated antenna and active tag and of a number of smaller receptacles in the form of pill bottles with passive tags integrated therein.

[Para 40] FIG 7 is a schematic view of a warehouse with a number of RF-enabled receptacles, in the form of boxes having RFID tags integrated therewith, a field antenna for 2-way communication with the boxes, and a warehouse base station and server connected to the loop antenna.

[Para 41] FIG 8 is a schematic view of a warehouse with a number of RF-enabled receptacles, in the form of freight totes having RFID tags and antennas integrated therewith, a field antenna for 2-way communication with the boxes, and a warehouse server connected to the loop antenna.

[Para 42] FIG 9 is a schematic block diagram of RF-enabled components for use with a product or receptacle.

[Para 43] FIG 10 is a schematic view of an RF-enabled receptacle, showing the data stored therein, and a remote ASP server and connected Read-Only (write-once-only) CD recorder to create an audit trail shown by the data recorded therein.

[Para 44] FIG 11a is schematic plan view of a CD (compact disc) as a RF-enabled product.

[Para 45] FIG 11b is a cross-section along A-A of the CD shown in FIG 11a.

[Para 47] FIG 12b is a cross-section along A-A of the meat tray shown in FIG 12a.

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#### Detailed description

[Para 48] According to an embodiment of the present invention, the RFID tag is integrated into, and forms part of the receptacle (e.g. container, package, tote, pallet) itself---- to make the package the tag and the tag the package. In one preferred embodiment the package would be an injection-molded two-piece plastic box (with a top and a bottom), with electronics display and light emitting diodes (LED's) on the front of the plastic box. The inside of the box may have a light sensor/detector connected to the processor to indicate that it has not been opened as well as to provide history when the box was opened and closed during manufacturing. Optional buttons might be placed on the front of the package, so that when it becomes shrink wrapped with a plastic vacuum bag the buttons are depressed. Again, this provides a record of when the receptacle/package was sealed as well as when it was opened and thus an indication that the medical device (e.g. stent) package has not been tampered with until it goes into the patient. The display on the front of the package can be an alphanumeric display (e.g. LCD or liquid crystal display) and can be used to indicate the lot number, expiry dates, or any other critical information about the product held by the receptacle that might be useful to an end-user or to a person working in the warehouse. The LEDs could be used to indicate the product is expired and should not be used; alternatively, the LED indicators could also be flashed to indicate that this package is the next one to use when placed in a stack on a shelf. Other parameters such as temperature, jog history, humidity, can also be recorded and display on the LCD.

[Para 49] A great advantage of placing the electronics within the receptacle or package

orientations on the receptacle, thereby increasing the strength of signal detected by the antenna, especially for lower frequencies of detected RF signal. According to the present invention, low frequencies not exceeding 15 megahertz, and advantageously not exceeding 1 megahertz, are preferred for use with such larger integrated antennas . In the case of a box receptacle, for example, loops of the antenna may be integrated, as by embedding into, the top, a side, and/or the back of the box, and thus a much larger area may be used for the antenna as compared to a conventional stick-on RFID tag or credit card size tag.

[Para 50] Advantageously, such a large antenna, which can be integrated into the receptacle in

[Para 51] multiple orientations, can either a) be part of an RFID tag that is integrated into an object (a product or a receptacle for holding products) or (b) be a separate signal enhancement antenna (e.g. a ferrite loop) which can communicate at a close distance with a separate antenna of an RFID tag that is attached or integrated into the object.

[Para 52] As will be understood, there are many have unexpected advantages of incorporating an RFID tag or an antenna with an object (either a product such as a CD, or a receptacle /package itself), making a design which is more functional and at lower cost. In most cases these high-value assets are distributed within a "closed loop" supply chain—a supply chain that is controlled by a single entity, thereby enabling recycling of receptacles or boxes which are integrated with a large separate antenna or with a complete RFID tag. The ability to recycle receptacles/boxes, that have embedded RFID tags which store data (in a memory or data storage device) about the history of the receptacle and the conditions it has experienced, is also advantageous since the recycled receptacles can be used as proof of use and for settlement purposes. It would be possible to include in the memory (data storage device) of the box the full pedigree of history of the product's use from the date of

its manufacture to the name and address of delivery to the final customer/enduser (e.g. hospital patient)..

[Para 53] FIG 1 shows a typical RF-enabled receptacle 2, in the form of a Smart package/box, with an antenna 3 embedded into at least one side of container 2, a (LCD) liquid crystal display 5, two light emitting diodes 6, three buttons 7, and optional temperature and humidity sensors/detectors 8, as well as a light sensor/detector 8 placed inside of the box 2. The buttons 7 could be used to indicate that the item has been moved or opened or other purposes requiring human input. The buttons 7 also can be designed so that when the box 2 is shrink-wrapped with plastic film, the buttons 7 are compressed, thereby providing a recordable indication that the package 2 is sealed, which can be used to prove that no one has tampered with this package 2.

[Para 54] FIG 2 is a schematic diagram for a RF-enabled box 2 and an RF-enabled product 1 (e.g. a bagged stent), with its own integrated antenna 3a and integrated passive RFID tag 4a. This box 2 and its tag 4a is similar to other radio frequency tags; however the printed circuit board and component parts shown in FIG 9 would be embedded into the plastic case portion for the box 2. The detector is might be placed inside of the box, and the loop antenna 3b shown in the block diagram may be placed on the top bottom or side of the box. It is also possible to place the loop antenna 3b on all three sides of the box to provide for enhanced and angle resistant communication. One of the major advantages of an RF-enabled product 1, package 2 , or other object, over a more standard RFID tag is that the antennas 3a, 3b can be much larger, and antenna 3b can be in all three axes. A second advantage of a RF-enabled box/ package 2 over a tag affixed to the exterior of a box is that sensors 8 may be selectively placed both inside the box 2 and outside the box 2. Moreover, an active RFID tag 4b can be used to interrogate the passive responder tags 4a that are

[Para 55] FIG 3 shows that another advantage of an RF-enabled ("smart") box 2 over a standard tag is that the layout and positioning of the LCD display 5 and LED's 6 can be optimally configured for storage on a shelf. The boxes 2 may be stout and stackable vertically or in other cases horizontally, and the form factor for thick boxes versus thin boxes etc. may be taken into account. Displays 5, buttons 7 and LED's 6 may be placed in the appropriate place for optimal storage and optimal use depending upon the product to be stored in totes 2 on shelving racks in a warehouse. It is possible to place a field loop antenna (see antenna 9 in FIGS 7 and 8) around a set of boxes 2 and communicate wirelessly to all smart boxes contained in such a field loop 9. This enables full product audits, inventory tracking, checks of status (i.e. has the box been opened and is—it/has—it—always-been at the correct temperature etc.) with no human intervention. This makes it possible to generate a full product pedigree while products are stored in such RF-enabled boxes 2 either directly on a data storage device of the RFID tag integrated into the smart box 2 or the data received by antenna 9 may be stored on a local write-once-only CD or (via a warehouse web server 11 satellite and the internet) on a remote write-once-only CD.

[Para 56] FIG 4 and FIG 5 show that a number of RF-enabled boxes 2a (with integrated antennas 3a, tags 4a, LCD displays 5a, LED's 6a, and buttons 7a) can be placed in/on a larger RF-enabled tote or pallet 2b which can be sealed and placed in the back of a truck equipped with a field antenna system 9 similar to that described in FIGS 7, 8. All boxes 2a could then be checked by interrogation from tags 4b of totes /pallets 2b and confirmed while being transported with GPS locations provided along with current temperature, time as depicted by data logs in FIG 10. These data logs would become part of the full product pedigree, and stored both in the smart box 2 as well as on a CD 17 connected to an ASP 16.

[Para 57] FIG 11a is schematic plan view of a CD (compact disc) as a RF-enabled product! with an integrated antenna 3 and RFID tag 4 embedded therein, while FIG 11b is a cross-section along A-A of the CD shown in FIG 11a!

[Para 58] FIG 12a is schematic plan view of a meat tray 2 as a RF-enabled receptacle with a large embedded antenna 3 (substantially as large as the two largest dimensions of tray 2 ) and an embedded RFID tag 4, which can alternatively be attached directly to product 1 (a beef steak) . FIG 11b is a cross-section along A-A of the meat tray shown in FIG 11a.

[Para 59] While the present invention has been described with reference to preferred embodiments thereof, numerous obvious changes and variations may readily be made by persons skilled in the fields of asset tracking and RFID tags. Accordingly, the invention should be understood to include all such variations to the full extent embraced by the claims.